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RESEARCH MEMORANDUM

LOW-SPEED WIND-TUNNEL INVESTIGATION OF A FIXED AND A FREE-FLOATING WING-TIP AILERON ON A WING WITH LEADING EDGE SWEPT BACK 51.3°

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NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

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RESEARCH MEMORANDUM

LOW-SPEED WIND-TUNNEL INVESTIGATION OF A FIXED AND A FREE-FLOATING WING-TIP AILERON ON A WING WITH LEADING EDGE SWEPT BACK 51.3°

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SUMMARY

A low-speed wind-tunnel investigation was made on a semispan wing swept back 51.3° at the leading edge with an aspect ratio of 4.47 and an NACA 65_1-012 airfoil section normal to the 0.556 chord line to determine the effectiveness of a half-delta tip aileron throughout a large angle-of-attack range. Two types of tip ailerons were tested: one a half-delta tip aileron and one a free-floating half-delta tip aileron with a servotab.

The results of the investigation indicated that the rolling effectiveness of either aileron was maintained up to very large angles of attack. The yawing moment caused by aileron deflection, however, was more favorable through the angle-of-attack range for the free-floating aileron.

INTRODUCTION

The National Advisory Committee for Aeronautics is currently investigating various devices for use in providing adequate lateral control on transonic and supersonic wing configurations. Some consideration has been given to wing-tip ailerons because of the advantages claimed for this type of control, such as: large rolling-moment arm available, possibility of locating the hinge axis so as to reduce the aileron hinge moments, and the possibility of installing full-span high-lift devices on the main wings.

Previous investigations of wing-tip ailerons deflected from a free-floating position have been made on unswept wings and have shown that lateral control could be obtainable beyond the wing stall with this type of aileron. The results of a preliminary investigation of a triangular wing-tip aileron on a 42° sweptback wing showed that this control surface may be used advantageously on swept-wing plan forms at subsonic and transonic speeds (reference 1). A high-speed investigation (reference 2) indicated that the rolling effectiveness of the wing-tip ailerons was lower than that of comparable flap-type ailerons at subsonic speeds but considerably higher at supersonic speeds.

The present investigation in the Langley 300 MPH 7- by 10-foot tunnel was made to determine the effectiveness of a fixed and a free-floating tip aileron at low speeds on an aspect-ratio-4.47 tapered wing swept back 51.3° at the leading edge. The wing was equipped with a triangular tip aileron of half-delta plan form, the free-floating aileron having a servotab. The control characteristics were obtained at low speeds through a large angle-of-attack range for the aileron at fixed deflections and with the aileron free-floating.

SYMBOLS

The forces and moments measured on the wing are presented about the wind axes which, for the conditions of these tests (zero yaw), correspond to the stability axes. The axes intersect at the intersection of the chord plane and the 22-percent station of the mean aerodynamic chord at the root of the model (figs. 1 and 2).

The symbols used in the presentation of results are as follows:

C_L lift coefficient (Twice lift of semispan model/qS)

C_D drag coefficient (D/qS)

C_m pitching-moment coefficient $(M/qS\bar{c})$

C_l rolling-moment coefficient caused by aileron deflection (L/qSb)

C_n yawing-moment coefficient caused by aileron deflection (N/qSb)

$\bar{c}$ wing mean aerodynamic chord including aileron, feet $\left(\frac{2}{S}\int_0^{b/2} c^2 dy\right)$

c local wing chord, feet

b twice span of semispan model including aileron, feet

y lateral distance from plane of symmetry, feet

S twice area of semispan model including aileron, square feet

D twice drag of semispan model, pounds

M twice pitching moment of semispan model about Y-axis, foot-pounds

L rolling moment, resulting from aileron deflection, about X-axis, foot-pounds

N yawing moment, resulting from aileron deflection, about Z-axis, foot-pounds

q free-stream dynamic pressure, pounds per square foot $\left(\frac{1}{2} \rho V^2\right)$

V free-stream velocity, feet per second

ρ mass density of air, slugs per cubic foot

α angle of attack with respect to root chord, degrees

δ_a aileron deflection, measured between wing-chord plane and aileron-chord plane (trailing edge down, positive), degrees

$C_{l_\delta} = \left(\partial C_l / \partial \delta_a\right)_\alpha$

δ_t tab deflection, measured normal to the tab hinge line (trailing edge down, positive), degrees

MODEL AND APPARATUS

The semispan sweptback-wing model was mounted vertically in the Langley 300 MPH 7- by 10-foot tunnel as illustrated in figure 3. The root chord of the model was adjacent to the ceiling of the tunnel, which served as a reflection plane. A small clearance was maintained between the model and the tunnel ceiling so that no part of the model came in contact with the tunnel structure. A small end plate was attached to the root of the model to deflect the spanwise flow of air that enters the tunnel test section through the clearance gap.

The model was built of aluminum with the dimensions shown in figure 2 and table I. The wing plus aileron had an aspect ratio of 4.47 and the leading edge of the model was swept back 51.3°. The wing sections perpendicular to the 0.556 chord line were of NACA 65_1-012 airfoil section.

The triangular tip aileron (fig. 2) was constructed of $\frac{1}{8}$-inch sheet aluminum with rounded leading and tapered trailing edges. The aileron was attached to the model by a steel shaft mounted in two bearings that allowed the aileron to be locked in position or to float freely. A full-aileron-span constant-chord servotab was used to deflect the free-floating aileron and the deflections were visually measured by using the end-plate protractor shown in figure 2 that was attached to the wing at the wing-aileron juncture.

CORRECTIONS

The angle-of-attack and drag data have been corrected for jet-boundary (induced-upwash) effects according to the methods outlined in reference 3. Blockage corrections were applied to the test data by the methods of reference 4.

Reflection-plane corrections were not applied to the rolling-moment and yawing-moment data. However, by extrapolation of the correction data of reference 5, it is estimated that the values of C_l presented herein were approximately 10 percent high. In addition, the corrected yawing moments would be generally more adverse than indicated by the data. No corrections were applied to account for the effects of the end plate (protractor) which was present during both the free- and fixed-aileron tests.

TESTS

The 51.3° sweptback wing with the triangular wing-tip aileron was tested in the Langley 300 MPH 7- by 10-foot tunnel at a dynamic pressure of approximately 50.8 pounds per square foot, which corresponds to a Mach number of 0.19 and a Reynolds number of about 2.4×10^6, based on the mean aerodynamic chord of the wing plus aileron.

The tests were made through an angle-of-attack range from -44° to 36° for fixed-aileron deflections from 0° to 20°, and for tab deflections from 0° to 20° with the aileron free-floating. No restraint or limit was placed on the aileron deflection when free-floating.

RESULTS AND DISCUSSION

The longitudinal aerodynamic characteristics of the test model are presented in figure 4 for both the fixed- and the free-floating-aileron conditions. The wing static longitudinal stability was less for the free-floating aileron and became unstable at lower values of lift coefficient than for the fixed aileron. When the aileron was allowed to float free there was a reduction in lift-curve slope and a decrease in the maximum lift coefficient of the wing. These changes in the aerodynamic characteristics resulted from the small contribution of the aileron when it was allowed to float free (fig. 5).

The variation of aileron deflection with tab deflection (fig. 5) indicated that the tab is effective throughout the angle-of-attack range investigated. In addition the variation of δ_a with δ_t is very nearly linear for δ_t deflections of $\pm 8^\circ$ and essentially independent of angle of attack. Either the fixed or free-floating aileron was effective in producing roll up to angles of attack of 40°. The loss in effectiveness with angle of attack appears to be very similar for the two configurations (figs. 6 and 7). The lateral control characteristics of the wing with both the fixed and free-floating ailerons are given in figures 6, 7, and 8.

In figure 8, in which the rolling and yawing moments are treated as resulting from a combination of left and right control deflections on a complete wing, it will be noted that, for this particular configuration the free-floating aileron appears to offer no advantages from the effectiveness point of view over the fixed-aileron deflection except for an angle of attack of 10° at deflection angles below 23°. Beyond a total tab deflection of approximately 20°, the effectiveness begins to fall off for all angles of attack except 5°.

For a given rolling-moment coefficient, particularly at high angles of attack, the free aileron did, however, have considerably less adverse yawing moment than the fixed aileron. This resulted from the fact that the free-floating aileron was deflected from an angle approximating zero angle of attack (fig. 5) while the fixed aileron was deflected from a position corresponding to the angle of attack of the wing.

The value of C_{l_δ} for the tip aileron of this investigation was about the same as that of a conventional flap-type outboard aileron of equal area (reference 6).

Some unpublished data concerning a 60° delta wing with a trailing-edge flap corresponding approximately to the trailing-edge tab of the half-delta tip aileron of this investigation indicate that the tab should be effective throughout the transonic speed range which should result in performance of a free-floating aileron equal to a tip aileron of fixed deflection.

CONCLUSIONS

A low-speed wind-tunnel investigation of a fixed and a free-floating wing-tip aileron on a semispan wing with leading edge swept back 51.3° led to the following conclusions:

1. The rolling effectiveness of both the fixed and the free-floating wing-tip aileron was maintained up to very large angles of attack.

2. The yawing moment caused by aileron deflection was more favorable throughout the angle-of-attack range for the free-floating aileron than for the fixed aileron.

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6. Lowry, John G., and Schneiter, Leslie E.: Estimation of Effectiveness of Flap-Type Controls on Sweptback Wings. NACA TN 1674, 1948.

TABLE I

PHYSICAL CHARACTERISTICS OF THE MODEL

[All dimensions in feet]

	Basic wing	Wing plus aileron
Wing:		
Area	12.06	12.53
Span	5.95	7.49
M.A.C.	2.08	2.00
Section (perpendicular to the 0.556 chord line)	NACA 65_1-012	------
Sweep (at leading edge) . . .	51.3°	------
Taper ratio	0.50	------
Aspect ratio	2.94	4.47
Aileron (one):		
Area	0.47	
Span	0.77	
Section	$\frac{1}{8}$-inch plate	
Sweep (at leading edge) . . .	60°	
Aspect ratio	1.28	
Tab (one):		
Area	0.10	
Chord	0.13	

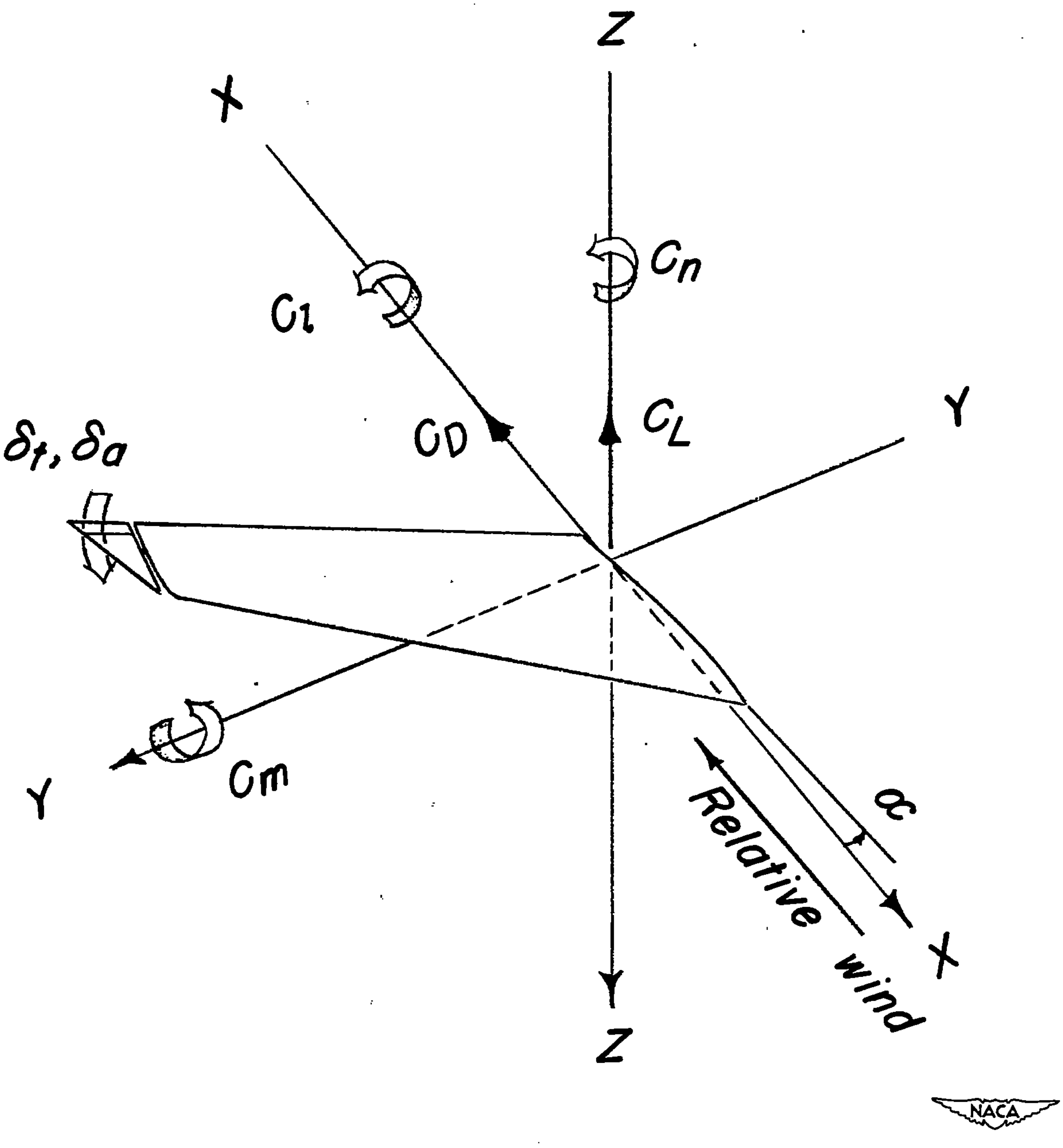


Figure 1.- System of axes and deflections showing positive directions of forces, moments, and deflections as indicated by the arrows.

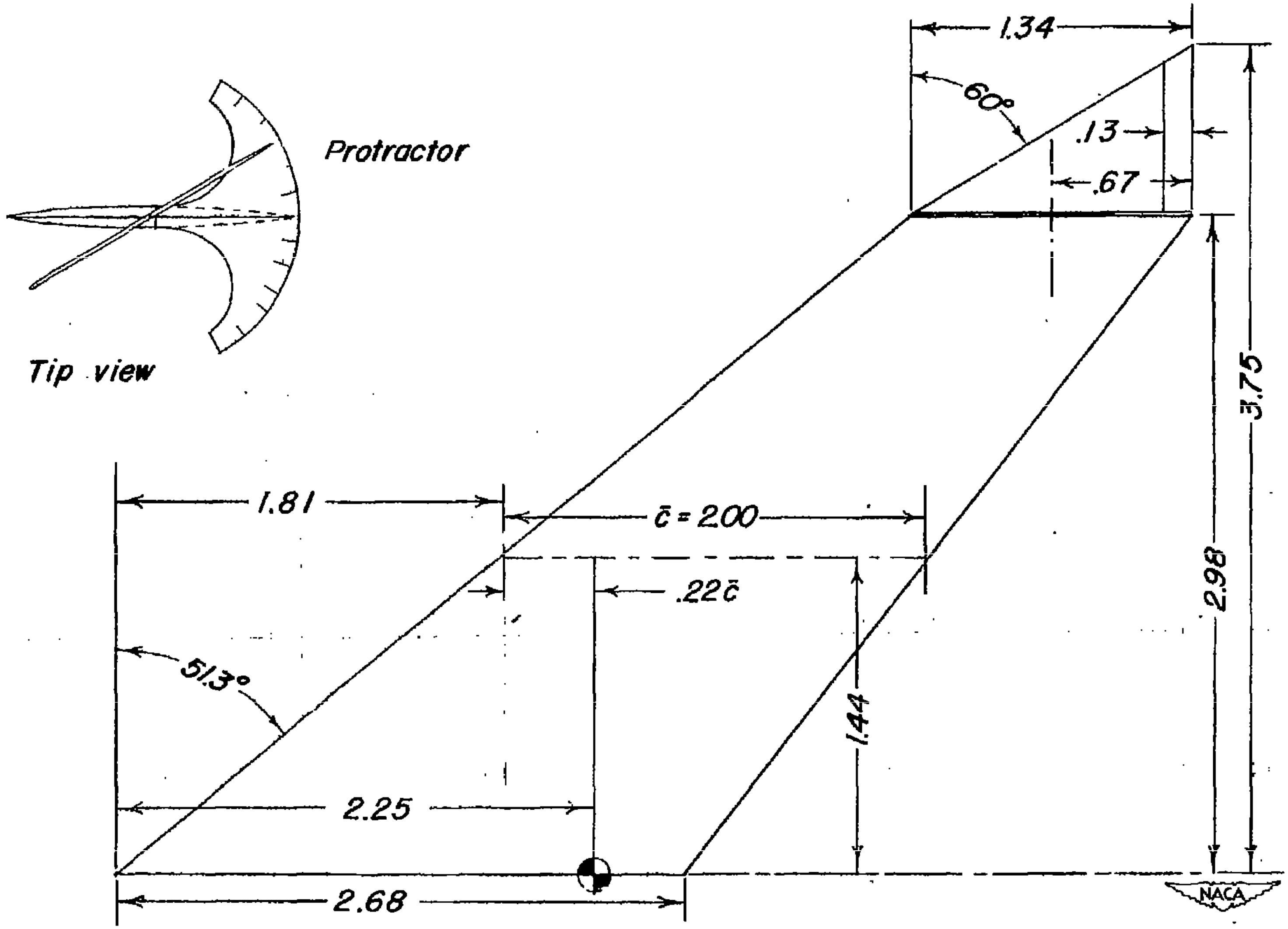


Figure 2.- Geometric characteristics of the 51.3° sweptback semispan wing with tip aileron. All dimensions are in feet.

[redacted]

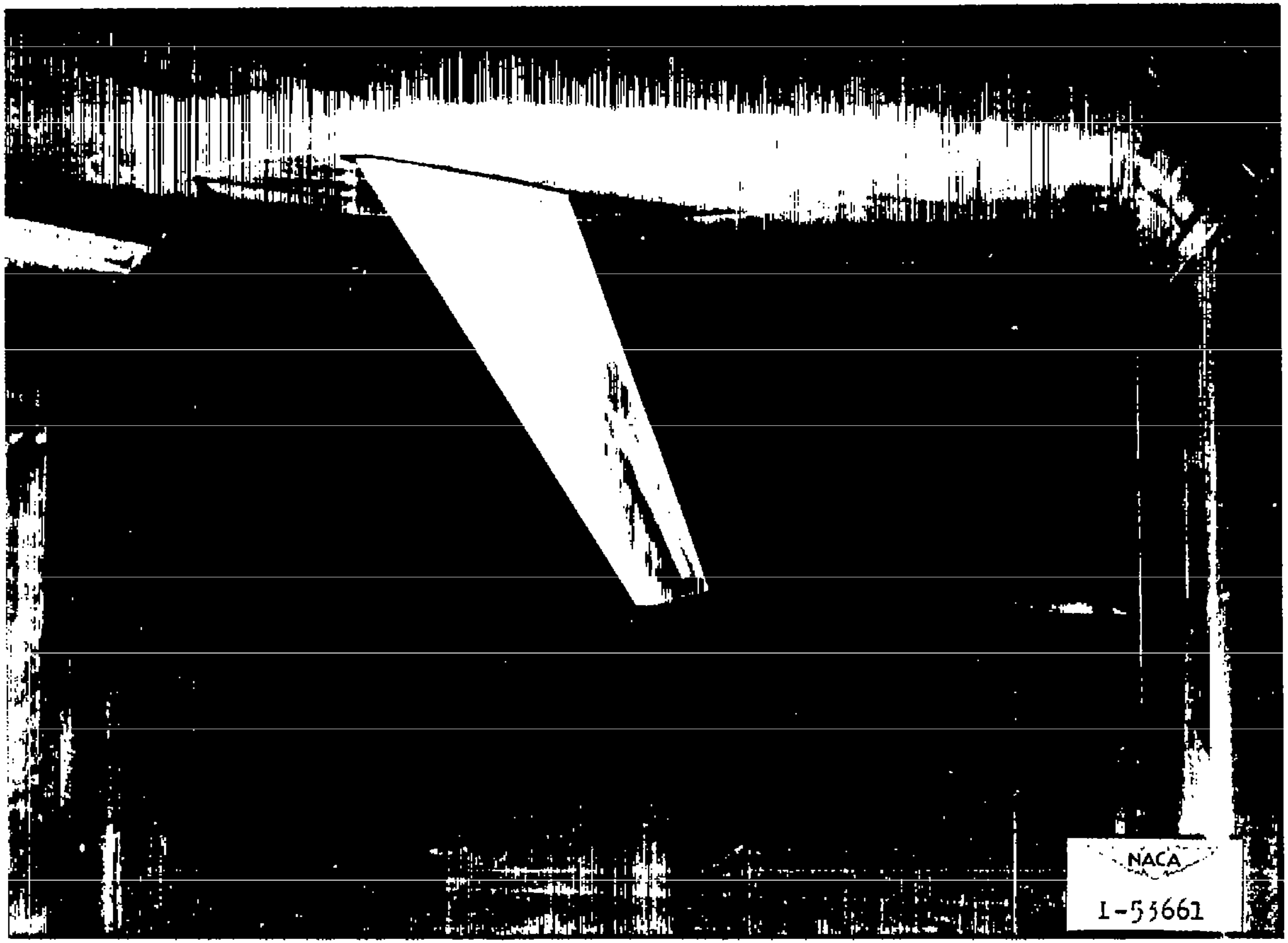


Figure 3.- The 51.3° sweptback semispan wing model mounted from the ceiling of the Langley 300 MPH 7- by 10-foot tunnel.

[redacted]

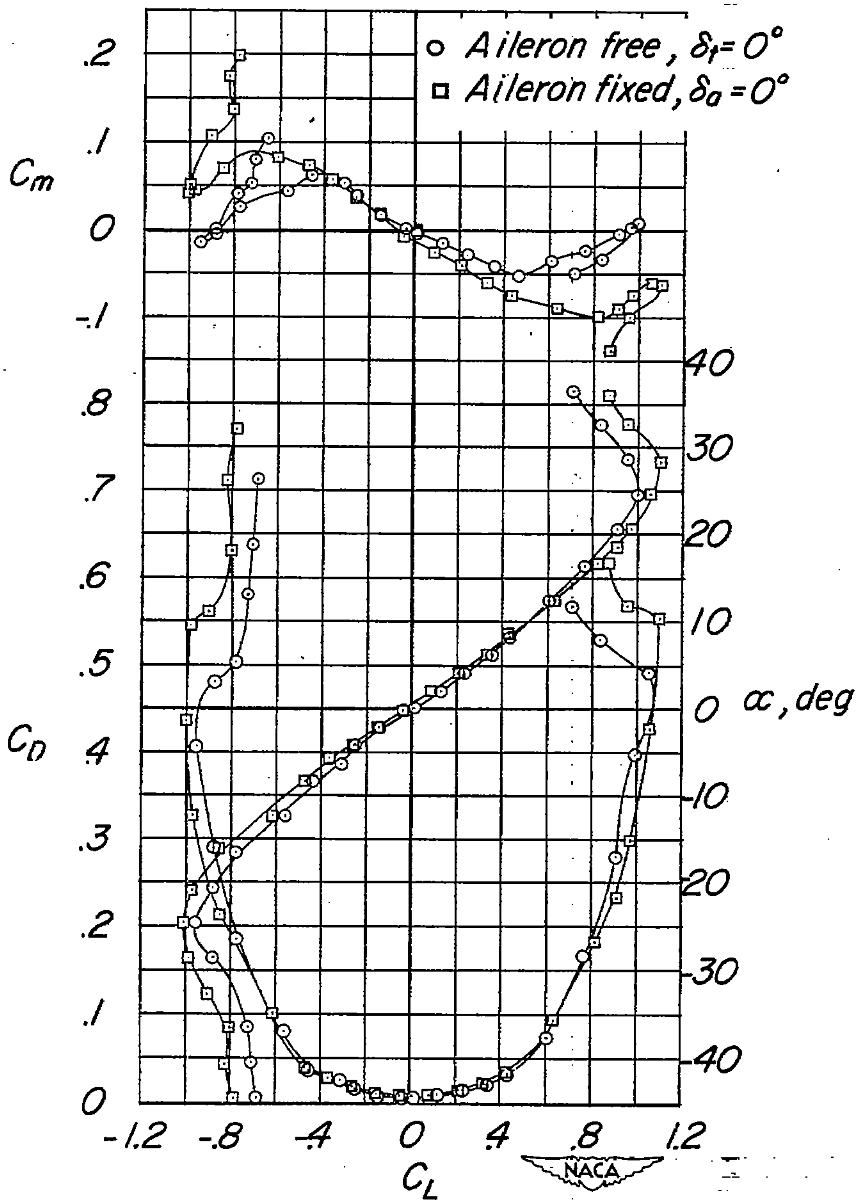


Figure 4.- Aerodynamic characteristics of the test model in pitch.

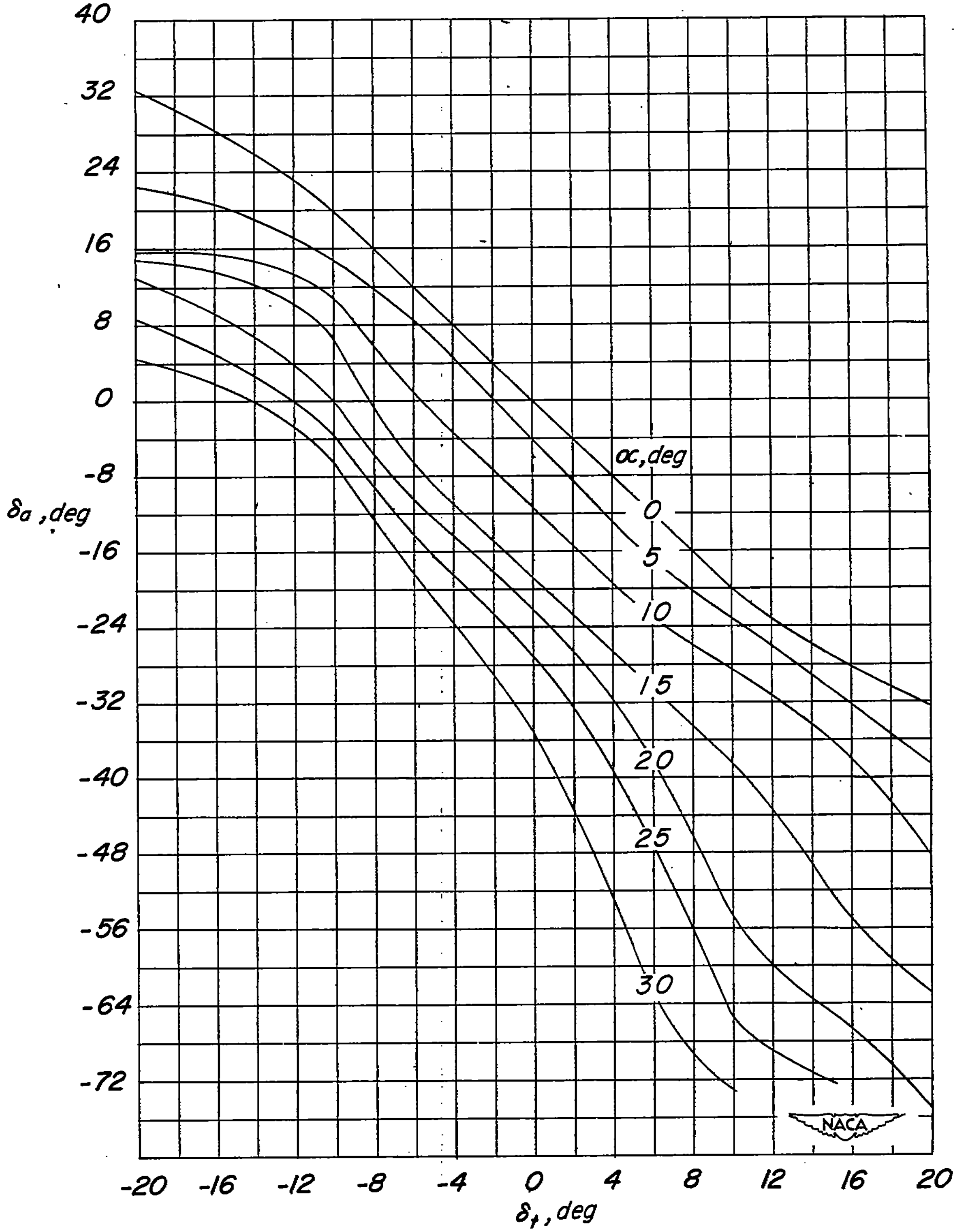


Figure 5.- Variation of aileron deflection with tab deflection for the test model.

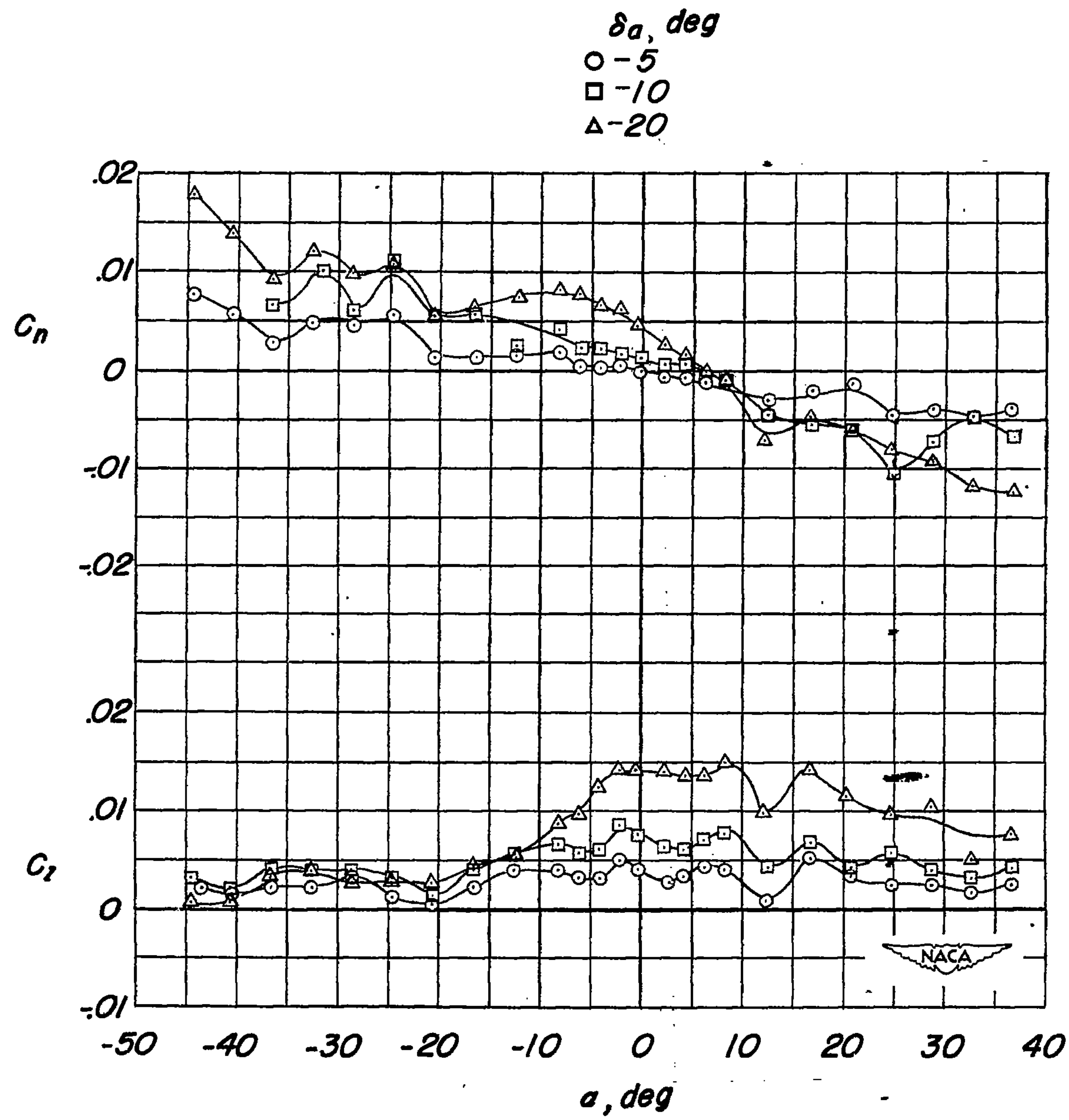


Figure 6.- The rolling-moment and yawing-moment characteristics of the model due to control deflection. Aileron fixed.

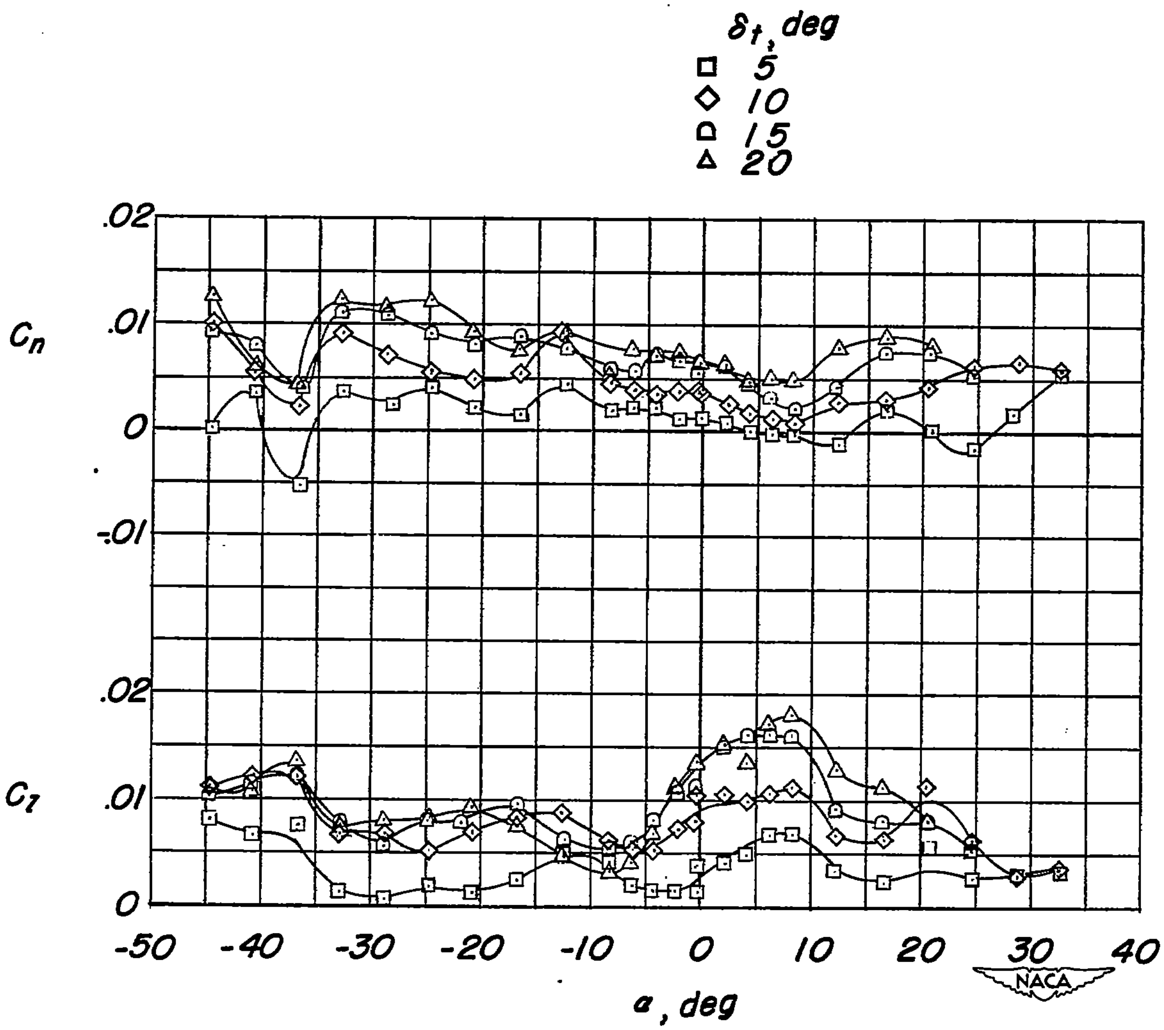
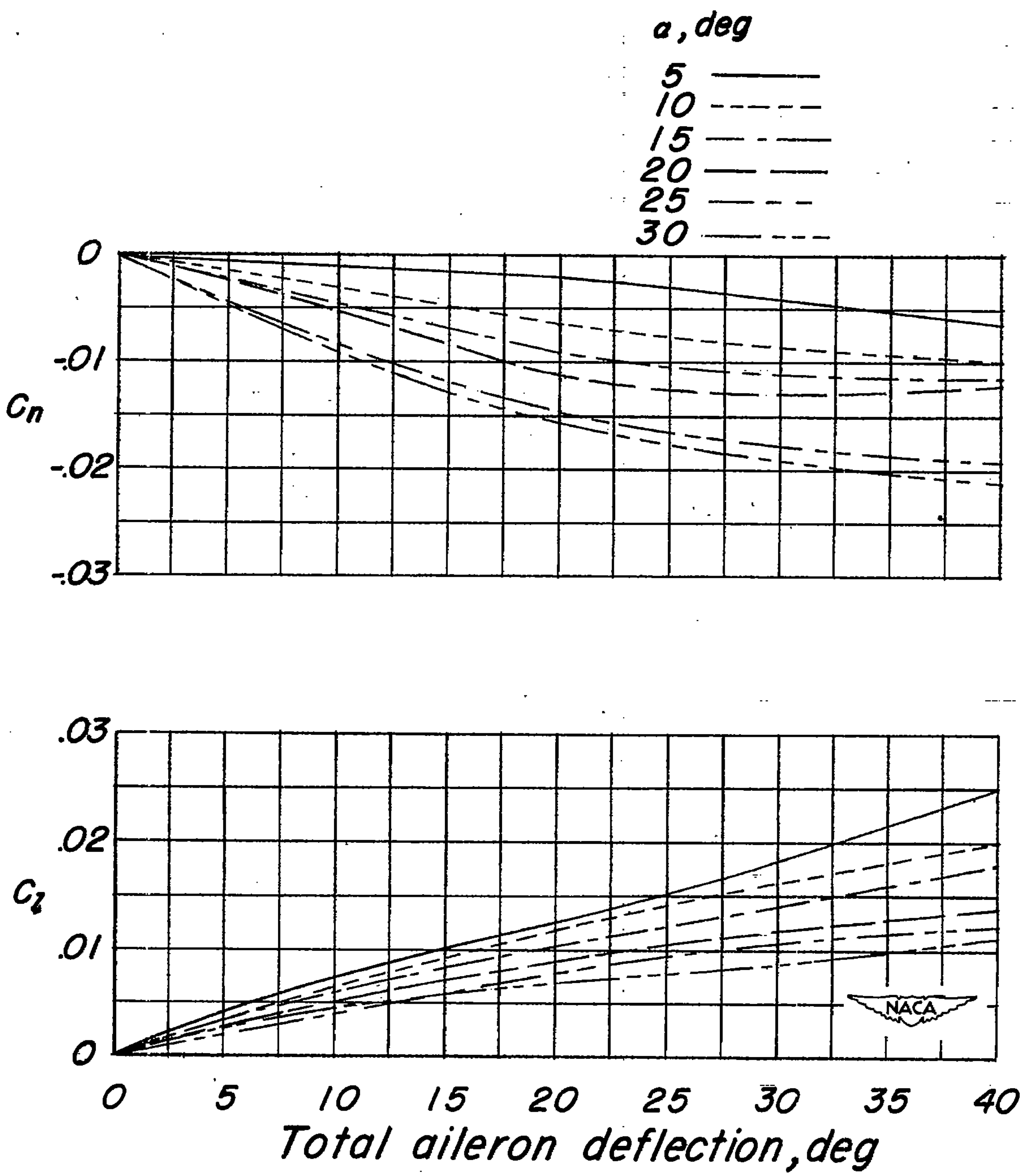
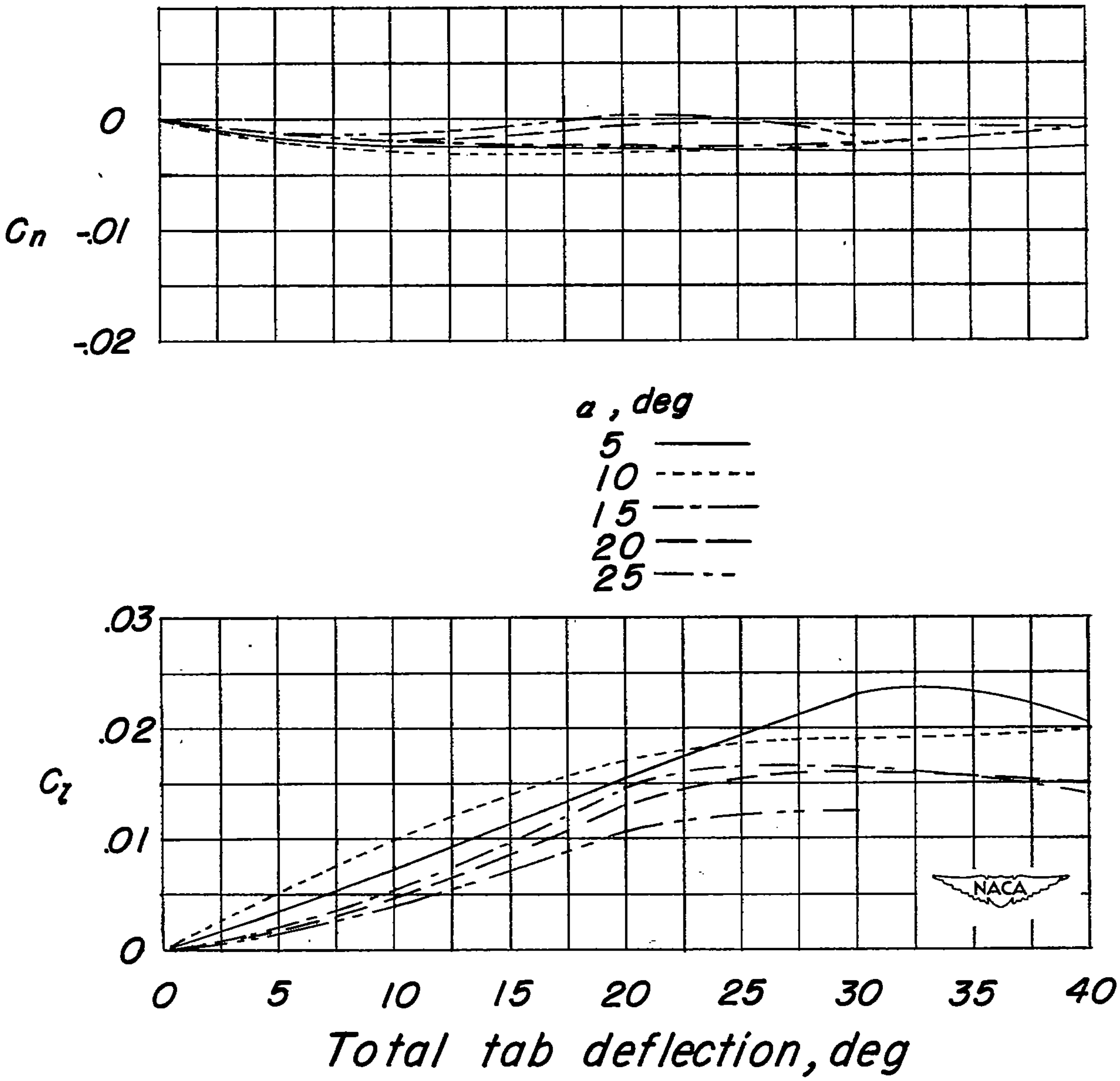


Figure 7.- The rolling-moment and yawing-moment characteristics of the model due to control deflection. Aileron free.



(a) Aileron fixed.

Figure 8.- The rolling-moment and yawing-moment characteristics resulting from a combination of left and right control deflections on a complete wing.



(b) Aileron free.

Figure 8.- Concluded.

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